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ASSESSING ORTHODONTIC-BRACKET IMPACTS ON LIP PROFILE AT
BONDING AND DEBONDING STAGES

Martin Trockel, D.D.S.

A Thesis Presented to the Faculty of the College of Dental Medicine of
Nova Southeastern University in Partial Fulfillment of the Requirements for the

Degree of

MASTER OF SCIENCE IN DENTISTRY

December 2015

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BONDING AND DEBONDING STAGES

By

MARTIN TROCKEL. D.D.S.

A Thesis Submitted to the College of Dental Medicine of Nova Southeastern
University in Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN DENTISTRY

Orthodontic Department

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December 2015

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TITLE OF SUBMISSION: ASSESSING ORTHODONTIC-BRACKET IMPACTS
ON LIP PROFILE AT BONDING AND DEBONDING STAGES
DATE SUBMITTED: December 1, 2015

I certify that I am the sole author of this thesis, and that any assistance I received in its preparation has been fully acknowledged and disclosed in the thesis. I have cited any sources from which I used ideas, data, or words, and labeled as quotations any directly quoted phrases or passages, as well as providing proper documentation and citations. This thesis was prepared by me, specifically for the M.Sc.D. degree and for this assignment.

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DEDICATION

To my loving wife for her support, motivation and understanding

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Abstract

ASSESSING ORTHODONTIC-BRACKET IMPACTS ON LIP PROFILE AT BONDING AND DEBONDING STAGES

DEGREE DATE: DECEMBER 18, 2015

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Introduction: One factor that contributes greatly to the lower face appearance and orthodontists have the ability to affect is lip profile. Clinical assessment of the lip profile is an important element in the decision of orthodontic treatment planning and in the evaluation of treatment progress and outcome. Three known factors influence the lip profile; the lip thickness, the underlying bone, and the tooth position. The positions and inclinations of the anterior teeth can affect the lip position, but it is unclear whether orthodontic brackets bonded to the labial surface of anterior teeth move the lip position and thereafter change the lip profile. Therefore, it is necessary to determine if orthodontic brackets bonded to the labial surface of the anterior dentition have any impact on lip profile.

Objective: The objective of this project was to determine the effect that bonded brackets have on lip profile utilizing a standardized lateral photographic cephalogram analysis during the bonding and debonding stages.

Methods: To determine the effect of bonded brackets on lip profile, digital photographic cephalometry was used. The patient was seated against a white backdrop in the standardized natural head position. Photographs were taken 5 feet from the patient, centered and level with the middle of the tragus of the right ear and were digitally analyzed using Dolphin Imaging software. Photos were acquired from 4 time points: before bonding (BT₀) and after bonding (BT₁) for the bonding group, and before debonding (DT₀) and after debonding (DT₁) for the debonding group. Upper and lower lip to E-plane, subnasale and lower lip to H-Line, superior sulcus depth, nasolabial angle, Z angle, upper and lower lip protrusion, and upper and lower lip to S-line were measured and analyzed statistically. The correlation of tooth angulation, lip thickness (determined using existing cephalometric radiographs), and bracket thickness on effect of lip position was also determined.

Results: There are significant differences in all measurements of the lip profile, except superior sulcus depth and nasolabial angle, between BT₀ and BT₁ at the bonding stage. In the bonding stage, change in Z angle was correlated to initial lower lip thickness and change in upper lip protrusion was correlated to the initial upper lip thickness at the vermilion boarder and upper incisor bracket thickness. There was no significant difference noted between DT₀ and DT₁ at the debonding stage.

Conclusion: Brackets have a significant effect on lip profile when bonding labial orthodontic brackets. Brackets have no significant effect on lip profile when debonding brackets. Therefore, a direct clinical assessment of lip profile before debonding is valid with no interference imposed by bonded orthodontic brackets.

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Chapter 1: Introduction

1.1. Facial Proportion and Lip Profile

It is often said that beauty is in the eye of the beholder, nonetheless, many have tried to quantify beauty by determining proportions that are found in beautiful faces¹⁻⁴. Facial aesthetics are of utmost importance in our society, studies have even found that attractive people are likely to be more successful than their less attractive counterparts^{5,6}. Most people that seek orthodontic treatment have the desire to improvement their facial harmony. This harmony is a conglomeration of the relation of the teeth with each other, the integumental features of the face, and the proportions of the teeth with the soft tissue facial structures⁷. In addition to esthetics, facial soft-tissue also plays an important role in speech, and mastication⁸. Lip profile is one aspect of the soft tissue that contributes to facial proportions and beauty^{9,10}.

Ricketts¹⁰, Holdaway^{11,12}, Steiner^{13,14} and others^{1,9,15-18} have developed cephalometric norms for the soft tissue to aid in orthodontic treatment planning. Authors have stressed the importance of lip balance relative to the nose and chin^{1,9-18} and pointed out that retruded and protruded lips were unharmonious and unproportioned, and such faces were unattractive to orthodontists and lay persons¹⁰. Other authors^{19,20} found that both the layperson and orthodontist find procumbent lips less attractive.

1.2. Effect of Orthodontic Treatment on Lip Profile Changes

Many studies have been done to determine the effect that orthodontic treatment has on lip profile^{7-9,13,18,19,21-37}. Changes in lip profile due to orthodontic

treatment vary greatly. Some researchers have found a high degree of correlation between upper-incisor and upper-lip retraction^{7,29-31}. Other investigators have found that extensive changes to the dentition do not lead to proportional changes in the lip profile^{9,13,18,21,23,32-34} indicating that the soft tissue may be in part self-supporting^{9,38}. Another study found that, though the “lip posture can be influenced by tooth movement...there is a relaxed postural position of the lips which is independent...of tooth position.”⁹

Racial differences have also been studied^{24,25,35}. There is no differences in lip response to incisor retraction based on race³⁵, but rather incisor angulation and lip thickness, regardless of the race, have an effect on the reaction of the lip profile due to changes in the underlying hard tissue²⁴. Due to initial differences in incisor angulation, black patients tend to have a greater downward movement of the upper lip while white patients tend to have a greater backward movement of the upper lip when treated with extractions and retraction of the upper incisors²⁴. Black patients tend to have more proclined upper incisors which results in a greater downward displacement of the upper incisor and subsequently the upper lip, while white patients tend to have more upright upper incisors, which results in greater backward displacement of the upper incisor and upper lip²⁴. Black patients also tend to have thicker lips which results in a diminished response of the lips to incisor retraction^{25,35}.

Upper lip thickness tends to increase as upper incisors are retracted when measured at the end of treatment^{28,35}. During and after retention, the upper lip decreases in lip thickness, but is still thicker than the original dimension²⁸. The

significant increase remains 10 years post-retention²⁸. Thickness of the lower lip is not affected by orthodontic treatment^{28,35}. Relatively thin lips tend to have a greater response to incisor retraction than thick lips^{27,35}, and individuals with greater lip strain tend to have a greater response to incisor retraction than lips that are not under strain²⁷. However no direct proportion can be made based solely on lip thickness since labial response seems to be multifactorial and the lips are partially self supporting^{9,38}.

1.3. Bracket Effect on Lip Profile

Lee et al³⁹ examined the effect of bonded orthodontic brackets on lip profile using a three dimensional laser to assess patients immediately before and after bonding orthodontic brackets. They found significant anterior displacement of the upper and lower lip with upward displacement in the upper lip and downward displacement in the lower lip.

More studies have been done regarding the effect debonding labial orthodontic brackets has on lip profile⁴⁰⁻⁴⁴. Some found no significant changes in upper or lower lip position when brackets were debonded⁴³; others found significant posterior displacement in the lower lip and corners of the mouth^{41,44}, while others found significant posterior displacement in both upper and lower lips and corners of the mouth^{40,42}. No significant correlations to changes in lip profile were found based on lip thickness⁴², bracket type^{39,42}, or gender⁴² at the debonding stage.

1.4. Significance of Study

Among the research of bracket effects on lip profile various measurement tools were employed. These measurement tools were conventional lateral cephalometric radiographs⁴⁰, lateral profile photographs with no standardization⁴³, and three dimensional analysis using stereophotogrammetry^{41,44} or laser scan^{39,42}. In orthodontics, standardized lateral photographs in natural head position have been used widely in the assessment of facial profile^{45,46}. However, this standardized photograph has never been used in the assessment of bracket effects on lip profile. Therefore, this study will use standardized cephalometric photographs to determine if there is any change in lip profile with and without brackets bonded to the dentition. Since this study will use standardized photographs with a standard unit of length in each photo, we will be able to make both angular and linear measurements of the changes in lip profile during bonding and debonding of brackets.

1.5. Purpose, Specific Aims and Hypotheses

1.5.1. Purpose

The purpose of this study is to determine if labial orthodontic brackets bonded to the dentition have any effect on lip profile using standardized lateral cephalometric photographs. This is important to the orthodontist for many reasons. Lip position is very important for proper esthetics, when treating the patient it is helpful to know where the final position of the lip will be so proper mechanics can be employed to move the dentition to obtain optimal esthetics. This information will also allow the orthodontist to inform the patient of what to expect when braces are bonded and debonded. Most importantly, the knowledge gained can be used in comparing the clinical outcomes to the established data in publications for the best available results.

1.5.2. Specific Aims

- 1) Determine the effect of bonded brackets on lip profile in the sagittal dimension at bonding and debonding stages.
- 2) Determine the correlation between the changes in lip profile, if existing, to the underlying factors, such as lip thickness, incisor angulation, and bracket thickness.

1.5.3. Hypotheses

H₀:

- 1) There is no difference in lip profile with and without orthodontic brackets bonded to the anterior dentition during either bonding or debonding stages.
- 2) There is no correlation between the changes in lip profile to the underlying factors, such as lip thickness, incisor angulation, and bracket thickness.

Chapter 2: Materials and Methods

2.1. Study

Thirty patients for both bonding and debonding groups were proposed. During the study, thirty-six patients were obtained for the debonding group in the time that it took to collect the data for the thirty patients in the bonding group, hence the differential in group sizes.

2.1.1. IRB Approval

IRB approval to conduct research using existing patients undergoing orthodontic treatment was granted at Nova Southeastern University.

2.1.2. Ethical Issues

No potential ethical issues could be identified as part of this research study. All data collection complied with IRB and HIPAA regulations and all data was de-identified to ensure confidentiality.

2.1.3. Grant

This study was awarded a grant by the Health Professions Division at Nova Southeastern University.

2.2. Patient Size Estimate

Sample size was determined using the study by Lee et al³⁹ as a template in which 45 patients were evaluated before and after bonding and found to have significant power. Therefore, with a mean effect size of 0.492, α of 0.05 and power of 80%, it was found that a sample size of 27 for each treatment group and a total sample size of 54 was needed to complete our study based on a significant difference of 0.29 +/- 0.59 mm average difference. Since 27 was the minimum required to attain significance, a sample size of 30 was selected to improve the power of the study. Two treatment groups of 30 patients resulting in a total sample size of 60 patients were proposed for this study. During the time that it required to collect the data for 30 patients starting treatment (the bonding group), 36 patients that were finishing treatment (the debonding group) qualified for the study and photographs were acquired, therefore there are 36 patients in the debonding group.

2.3. Patient Selection

Patients either starting or finishing orthodontic treatment at Nova Southeastern University were selected and asked to participate in this study. Those starting treatment were asked to take pre- and post- bonding photographs to assess the effects of brackets on lip profile when bonding. Those about to finish treatment were asked to take pre- and post-debonding photographs to assess the effects of brackets on lip profile when debonding.

The inclusion criteria consisted of patients about to start or finish orthodontic treatment at Nova Southeastern University, and patients with

brackets on upper and lower anterior teeth (canine to canine). Age was not part of the inclusion criteria, nor was ethnicity.

The exclusion criteria consisted of patients with craniofacial or muscular deformities, and patients in the pre-bond group that had greater than ten degree rotation on any of the anterior dentition (crowding), or greater than 1 mm diastemas between any of the anterior dentition (spacing). **Figure 1** depicts the grouping of the patients, the timing of photos and the measurements done to determine changes in lip position.

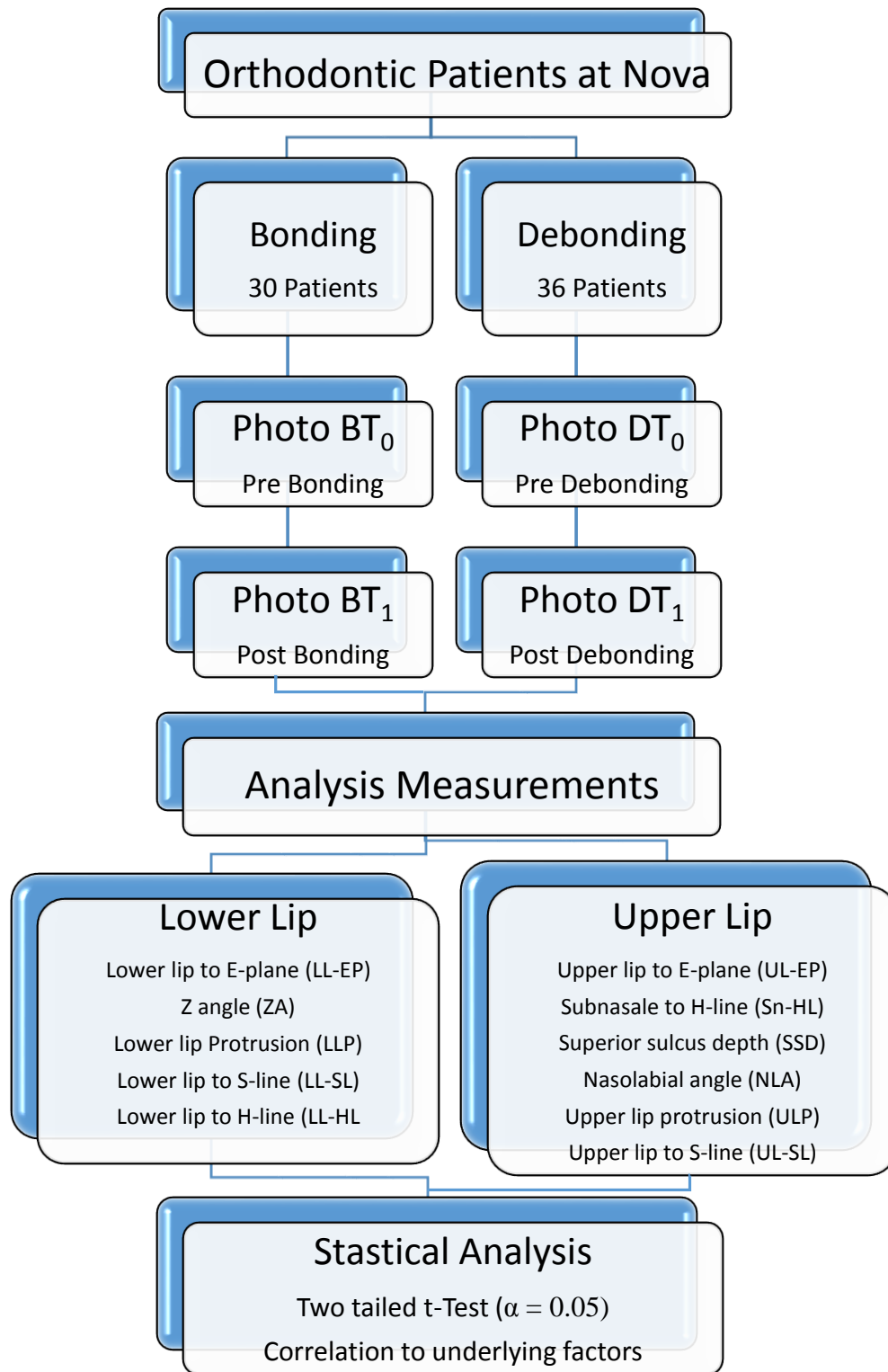


Figure 1: Flow chart depicting the separation of patients into separate groups, the timing of photographs, the data collection and analysis

2.4. Experiment

Photographs taken before and after bonding brackets, as well as before and after debonding brackets, were used to determine the effect of bonded brackets on lip position. **Figure 2** and **Figure 3** are the imaginary depictions of the patient with (**Figure 3**) and without (**Figure 2**) orthodontic brackets bonded.



Figure 2: Patient profile without brackets.

Figure 3: Patient profile with brackets.

All photos were taken by the same clinician, in the same location, with a Pentax K-x DSLR camera (*Ricoh Imaging Company Ltd, Tokyo, Japan*), using the same focal length of 55mm on a Pentax 18-55mm kit lens (*Ricoh Imaging Company*

Ltd, Tokyo, Japan), ISO setting of 200, aperture of 5.6, and flash setting of $\frac{1}{4}$ power on Viltrox Macro Ring Lite JY670 (*Shenzhen City grand shadow Technology Co Ltd, Longhua City, China*). The photos were taken from a distance of 5 feet (the standard source to object distance used in lateral cephalometric analysis) from the mid sagittal plane with the patient oriented in natural head position^{45,46} with a Bosch Model # GLL2-10 Cross Line Self Leveling Laser Level (*CPO Commerce, Pasadena, CA*) placing horizontal lines to ensure that the camera was level with the patient at the level of the tragus. An object (aluminum bar) of known length of 100 mm was placed directly in front of the

patient and just above the level of the eyes in the mid-sagittal plane to not interfere with natural head position. The Bosch DLR130K Digital Distance Measurer (CPO Commerce, Pasadena, CA) attached to the camera assembly (camera, laser level, digital measurer), seen in **Figure 4**, determined the distance of 5 feet between camera and the right tragus of the patient. The camera and laser level were centered on the patient's right tragus.

They were seated upright, perpendicular to the wall, looking at their own eyes in

the mirror in front of them, and were instructed to relax their lips with their upper and lower teeth in occlusion⁴⁶. **Figure 5** depicts a patient seated in natural head position with the laser level and laser distance measure device, plumb line, and object of known length in proper orientation.



Figure 4: Camera setup for taking standardized photographs. Pentax Camera with ring flash mounted with a laser distance measure device and laser level atop a tripod.

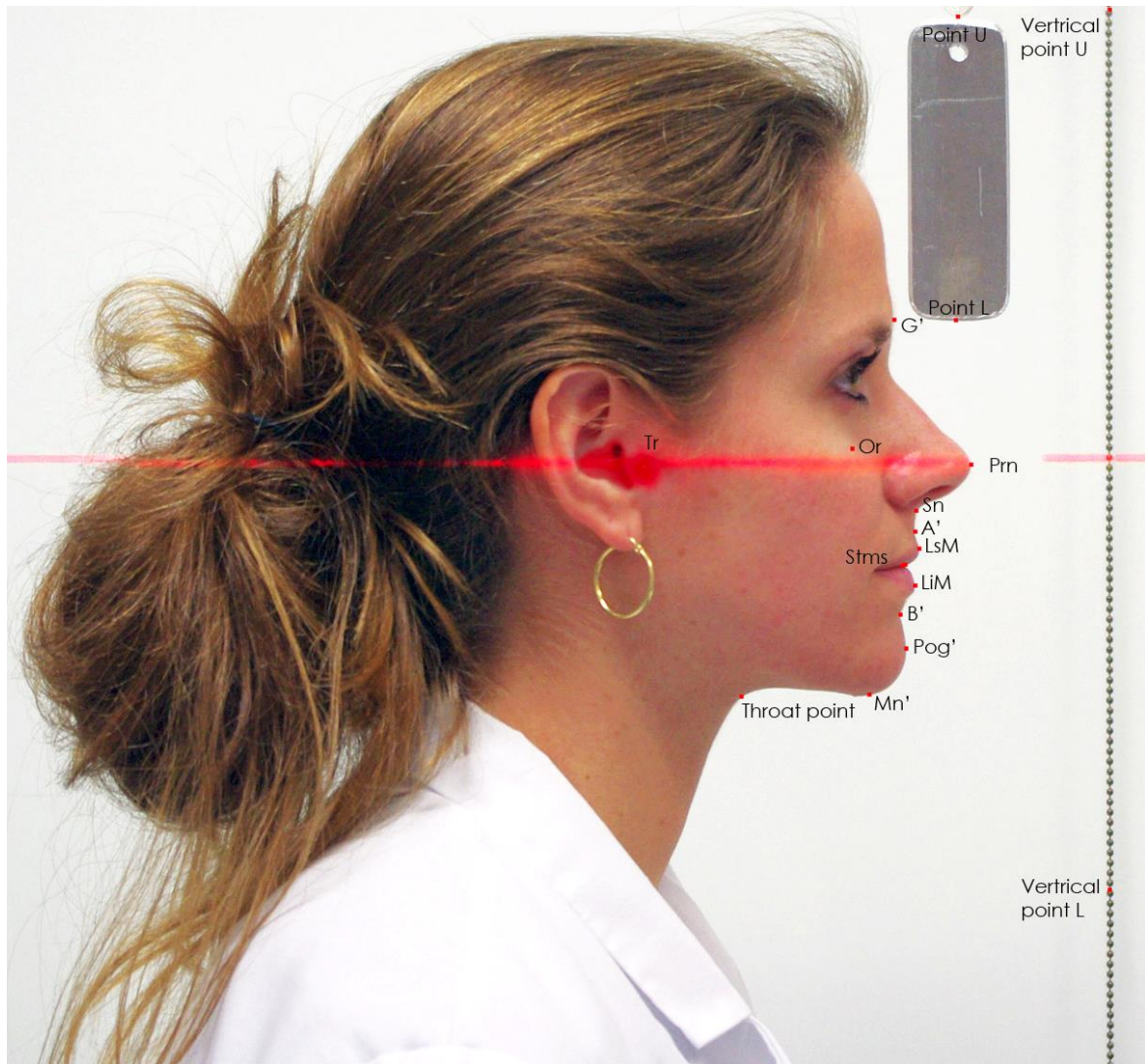


Figure 5: Standardized photograph taken of patients before and after either bonding or debonding. Laser level was placed through the mid tragus, laser point from laser distance measure device was placed mid tragus, patient was seated 1 centimeter behind the hanging ruler (100 mm in length) and a plumb line was hung in front of the patient to determine true vertical.

Vertical point U: uppermost point for vertical reference, Vertical point L: lowermost point for vertical reference, Point U: upper point on ruler, Point L: lower point on ruler, G': soft tissue glabella, Or: orbitale, Tr: tragion, Prn: pronasale, Sn: subnasale, A': soft tissue A point, LsM: labrale superius midline, Stms: stomion superius, LiM: labrale inferius midline, B': soft tissue B point, Pog': soft tissue pogonion, Mn: soft tissue menton, Throat point: throat point

Incisor inclination and lip thickness were determined for each patient using existing cephalometric radiographs. Bucco-lingual thickness of each bracket placed on central incisors (upper and lower) was measured using a digital caliper (Orthopli Corporation, Philadelphia, PA).

All photographs were digitized using Dolphin Imaging Software 11.5 (Los Angeles, California, USA). This software was used to define the anatomic landmarks and lip profile needed for this investigation. Assessments of lip profile, such as upper and lower lip relative to Ricketts E plane⁴⁷ (**Figure 6**), Subnasale and lower lip to Holdaway's H-line^{11,12} (**Figure 7**), upper and lower lip to Steiner S line¹⁴ (**Figure 8**), nasolabial angle¹⁵ (**Figure 9**), Z angle⁴⁸ (**Figure 10**), upper and lower lip protrusion⁹ (also known as Burstone B-line) (**Figure 11**), and superior sulcus depth (**Figure 12**) were performed in this study.

Duplicate tracings of ten randomly selected patients (photographic and radiographic cephalograms) were done at a time interval of no less than 1 month apart to establish intra-rater reliability, the mean differences were compared and the paired t-Test showed no statistical differences. Ten photographic cephalograms were randomly selected and traced by another operator and paired t-Test showed no statistical differences.



Figure 6: Rickets E-Plane (soft tissue pogonion to tip of nose)



Figure 7: Holdaway H-line (soft tissue pogonion to most protrusive point of upper lip)



Figure 8: Steiner S-line (soft tissue pogonion to center of the curve from subnasale to tip of nose)



Figure 9: Nasolabial angle (Columella tangent and upper lip tangent)

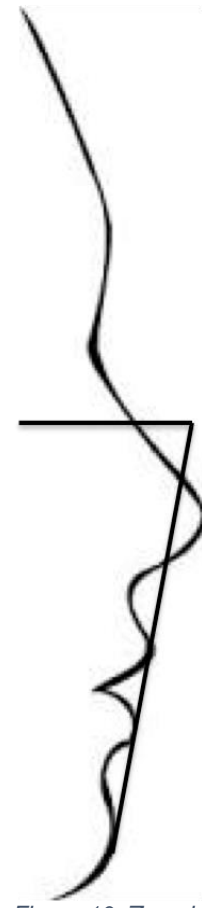


Figure 10: Z angle (angle of bisecting lines from soft tissue pogonion to most protrusive point of lower lip and Frankfurt horizontal)



Figure 11: Upper and Lower lip protrusion (Soft tissue pogonion to subnasale, perpendicular upper and lower lip)

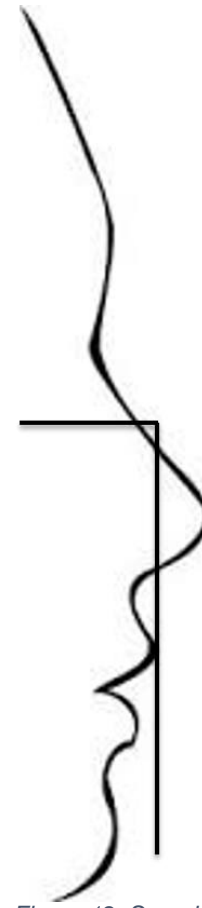


Figure 12: Superior sulcus depth (perpendicular to Frankfort and tangent to the vermilion border of the upper lip)

2.5. Data Storage

The de-identified data was entered and stored on an excel spreadsheet on a password protected computer at Nova Southeastern University.

2.6. Statistical analysis

For descriptive statistics, mean, standard deviation, median, minimum, and maximum by were calculated. For inferential statistics, a two-tailed t-Test ($\alpha=0.05$) was used to determine significant difference between the means of all profile measurement before and after bonding and debonding. A correlation analysis was used to determine the relation between the changes in lip profile and the lip thickness, incisor angulation, or bracket thickness. Strength of correlation is defined as weak if $|r|<0.3$, moderate if $0.3\leq|r|<0.5$, and strong if $|r|\geq0.5$ ⁴⁹. The R programming language for statistical computing (*RStudio*, Boston, MA) was used to perform the data analysis.

Chapter 3: Results

3.1. Immediate Bracket Effect on Lip Profile at Bonding

To determine the effect of brackets on the lip profile in the bonding stage, we compared all assessments of lip profile on the standardized photos immediately before (BT_0) and after (BT_1) bracket bonding. The mean, standard deviation, median, minimum and maximum for all lip profile measurements are listed in **Table 1**. Statistical analysis showed significant differences between BT_0 & BT_1 in all lip profile measurements, except superior sulcus depth (SSD) and nasolabial angle (NLA). The significant changes (BT_1-BT_0) are as follows: lower lip to E-plane (LL-EP) (1.29 ± 0.87 mm), lower lip to Holden line (LL-HL) (0.89 ± 0.58 mm), Z angle (ZA) ($-0.85 \pm 3.31^\circ$), lower lip protrusion (LLP) (2.32 ± 1.6 mm), lower lip to S-line (LL-SL) (1.3 ± 0.78 mm), upper lip to E-plane (UL-EP) (0.71 ± 0.88 mm), Subnasale to Holden line (Sn-HL) (1.03 ± 0.74 mm, $p=0.00045$), upper lip protrusion (ULP) (1.20 ± 1.05 mm, $p=0.0012$), and upper lip to S-line (UL-SL) (0.75 ± 0.74 , $p=0.0032$) (**Table 3**). All of the changes indicate a more protrusive upper and lower lip immediately after bonding orthodontic brackets to the labial surface of anterior dentition.

Upper Lip Measurements at Bonding

Lower Lip Measurements at Bonding

	Mean	S.D.	Median	Min	Max		Mean	S.D.	Median	Min	Max
UL-EP BT₀	-0.97	3.96	-1.87	-11.68	6.25	LL-EP BT₀	1.47	4.50	-1.36	-5.16	8.11
UL-EP BT₁	-0.26	4.07	-1.35	-10.20	6.90	LL-EP BT₁	2.76	4.56	1.44	-4.79	8.65
Sn-HL BT₀	7.59	4.02	6.41	-1.35	14.83	LL-HL BT₀	2.02	2.75	1.71	-0.57	6.79
Sn-HL BT₁	8.62	3.67	7.312	-0.41	15.03	LL-HL BT₁	2.91	2.91	2.39	-1.31	7.77
SSD BT₀	3.02	1.84	2.52	-2.40	5.78	ZA° BT₀	66.85	8.50	69.01	43.01	80.58
SSD BT₁	3.43	1.91	2.89	-4.11	6.40	ZA° BT₁	63.00	8.70	65.26	46.27	84.08
NLA° BT₀	105.20	8.96	106.19	91.56	119.57	LLP BT₀	3.32	4.87	1.74	-3.57	12.75
NLA° BT₁	101.59	8.48	105.25	87.77	126.80	LLP BT₁	5.64	5.19	2.88	-1.18	16.01
ULP BT₀	5.01	3.68	3.55	0.29	11.87	LL-SL BT₀	3.15	4.33	0.94	-2.74	8.99
ULP BT₁	6.21	3.56	4.13	1.44	12.30	LL-SL BT₁	4.46	4.26	3.33	-2.55	10.17
UL-SL BT₀	1.97	3.61	1.15	-7.13	8.48						
UL-SL BT₁	2.72	3.48	1.64	-5.93	8.86						

Table 1: Mean, standard deviation (S.D.), median, minimum, and maximum for all values measured in the bonding group. All measurements are in millimeters except NLA and ZA, which are in degrees.

UL-EP: Upper lip to E-plane, Sn-HL: Subnasale to H-line, SSD: Superior sulcus depth, NLA: Nasolabial angle, ULP: Upper lip protrusion, UL-SL: Upper lip to S-line, LL-EP: Lower lip to E-plane, LL-HL: Lower lip to H-line, ZA: Z angle, LLP: lower lip protrusion, LL-SL: Lower lip to S-line

3.2. Immediate Bracket Effect on Lip Profile at Debonding

To determine the effect of brackets on the lip profile in the debonding stage, we compared all assessments of lip profile on the standardized photos immediately before (DT₀) and after (DT₁) bracket bonding. The mean, standard deviation, median, minimum and maximum for all measurements are listed in **Table 2**. Statistical analysis showed that there are no significant differences between DT₀ & DT₁ in all measurements (**Table 4**). The results indicate there was no immediate change in the lip profile at the debonding stage.

Upper Lip Measurements at Debonding

Lower Lip Measurements at Debonding

	Mean	SD	Median	Min	Max		Mean	SD	Median	Min	Max
UL-EP DT₀	-2.08	2.84	-2.33	-7.47	3.98	LL-EP DT₀	0.71	3.40	0.47	-5.11	7.94
UL-EP DT₁	-2.12	2.65	-2.68	-6.70	3040	LL-EP DT₁	0.34	3.11	-0.28	-3.99	7.04
Sn-HL DT₀	6.77	3.09	6.50	2.41	13.43	LL-HL DT₀	2.03	1.97	1.95	-0.63	6.57
Sn-HL DT₁	6.79	2.87	6.29	3.14	13.07	LL-HL DT₁	1.69	1.86	1.27	-2.20	5.99
SSD DT₀	2.30	1.72	2.43	-0.50	7.02	ZA° DT₀	65.91	8.81	65.91	43.38	83.96
SSD DT₁	2.34	1.64	2.37	-1.16	7.11	ZA° DT₁	67.22	8.09	67.34	42.63	85.99
NLA° DT₀	107.93	11.20	107.66	73.73	127.58	LLP DT₀	3.26	4.66	2.23	-3.38	14.16
NLA° DT₁	108.00	11.20	107.66	80.16	124.83	LLP DT₁	3.16	4.94	2.58	-4.88	14.00
ULP DT₀	4.25	3.25	3.78	-1.82	11.98	LL-SL DT₀	2.56	3.15	2.40	-2.29	9.94
ULP DT₁	4.35	3.11	3.67	-0.30	11.69	LL-SL DT₁	2.21	2.87	1.76	-1.69	8.50
UL-SL DT₀	1.13	2.54	0.88	-3.19	6.48						
UL-SL DT₁	0.99	2.38	0.43	-2.39	6.13						

Table 2: Mean, standard deviation (S.D.), median, minimum, and maximum for all values measured in the debonding group. All measurements are in millimeters except NLA and ZA, which are in degrees.

UL-EP: Upper lip to E-plane, Sn-HL: Subnasale to H-line, SSD: Superior sulcus depth, NLA: Nasolabial angle, ULP: Upper lip protrusion, UL-SL: Upper lip to S-line, LL-EP: Lower lip to E-plane, LL-HL: Lower lip to H-line, ZA: Z angle, LLP: lower lip protrusion, LL-SL: Lower lip to S-line

Changes in Lip Profile at Bonding (BT₁-BT₀)

	Δ LL-EP	Δ LL-HL	Δ ZA°	Δ LLP	Δ LL-SL	Δ UL-EP	Δ Sn-HL	Δ SSD	Δ NLA°	Δ ULP	Δ UL-SL
Mean	1.29	0.89	-3.85	2.32	1.31	0.71	1.03	0.41	-3.61	1.20	0.75
S.D.	0.87	0.58	3.31	1.60	0.78	0.88	0.74	0.71	5.00	1.05	0.74
P-value	1.7e-4*	7.8e-5*	0.0042*	3.8e-7*	5.3e-7*	0.017*	4.5e-4*	0.59	0.57	0.0012*	0.0032*

Table 3: Mean, standard deviation (S.D.), and p-value for all measurements in bonding group. All measurements are in millimeters except NLA and ZA, which are in degrees.

* Statistically significant, $p < \alpha$, $\alpha = 0.05$

UL-EP: Upper lip to E-plane, Sn-HL: Subnasale to H-line, SSD: Superior sulcus depth, NLA: Nasolabial angle, ULP: Upper lip protrusion, UL-SL: Upper lip to S-line, LL-EP: Lower lip to E-plane, LL-HL: Lower lip to H-line, ZA: Z angle, LLP: lower lip protrusion, LL-SL: Lower lip to S-line

Changes in Lip Profile at Debonding (DT₁-DT₀)

	Δ LL-EP	Δ LL-HL	Δ ZA°	Δ LLP	Δ LL-SL	Δ UL-EP	Δ Sn-HL	Δ SSD	Δ NLA°	Δ ULP	Δ UL-SL
Mean	-0.37	-0.34	1.31	-0.10	-0.35	-0.03	0.02	0.04	0.07	0.10	-0.14
S.D.	0.97	0.78	3.53	1.75	0.93	0.85	0.94	0.63	3.57	0.80	0.93
P-value	0.069	0.075	0.067	0.57	0.082	0.68	0.85	0.75	0.56	0.87	0.31

Table 4: Mean, standard deviation (S.D.), and p-value for all measurements in debonding group. No values were found to have significance. All measurements are in millimeters except NLA and ZA, which are in degrees.

UL-EP: Upper lip to E-plane, Sn-HL: Subnasale to H-line, SSD: Superior sulcus depth, NLA: Nasolabial angle, ULP: Upper lip protrusion, UL-SL: Upper lip to S-line, LL-EP: Lower lip to E-plane, LL-HL: Lower lip to H-line, ZA: Z angle, LLP: lower lip protrusion, LL-SL: Lower lip to S-line

3.3. Correlation Between Changes in Lip Profile and the Underlying Factors

In the bonding groups, there are statistically significant changes in all of the lip profile measurements, except SSD and NLA. We further examined the possible correlations between the significant lip profile changes, such as LL-EP, LL-HL, LLP, ZA, LL-SL, UL-EP, Sn-HL, ULP, and UL-SL, and the underlying factors, such as incisor inclination, lip thickness, and bracket thickness.

In the lower lip at bonding, there is a significant moderate positive correlation between the changes in ZA and the lower lip thickness at B point (LLT@B) ($r=0.371$, $p=0.043$, 95% CI (0.012, 0.645)) (**Tables 5**). In the upper lip at bonding, there is a significant moderate negative correlation between the changes in ULP and upper lip thickness at vermilion boarder (ULT@VB) ($r=-0.379$, $p=0.039$, 95% CI (-0.650, -0.022)), as well as a significant moderate positive correlation between the changes in ULP and the upper incisor bracket thickness (U1-BT) ($r=0.451$, $p=0.012$, 95% CI (0.108, 0.698)) (**Table 6**).

Pearson Correlation Coefficients (r) between lower lip profile changes and underlying factors at bonding

	Δ LL-EP	Δ LL-HL	Δ LLP	Δ ZA	Δ LL-SL
FMIA°	0.143	0.261	-0.137	-0.093	0.250
L1-NB°	-0.026	-0.275	0.036	0.267	-0.354
LLT@B(mm)	-0.004	-0.240	-0.133	0.371*	-0.149
LLT-IO(mm)	-0.111	0.215	-0.118	-0.152	0.128
LL@U1(mm)	0.034	-0.276	-0.169	0.158	-0.171
L1-BT(mm)	-0.095	-0.142	0.184	-0.174	0.073

Table 5: Correlation coefficients (r) for lower lip profile changes at bonding. Correlation coefficients with significance have been emboldened.

*Statistically significant, $p=0.043$, $p<\alpha$, $\alpha=0.05$

LL-EP: Lower lip to E-plane, LL-HL: Lower lip to H-line, LLP: lower lip protrusion, ZA: Z angle, LL-SL: Lower lip to S-line, FMIA: Frankfurt to mandibular incisor angle, L1-NB: lower incisor to nasion-B point, LLT@B: Lower lip thickness at B-point, LLT-IO: Lower lip thickness inside to outside, LL@U1: Lower lip thickness at Upper incisor, L1-BT: Lower incisor bracket thickness.

Pearson Correlation Coefficients (r) between upper lip profile changes and underlying factors at bonding

	Δ UL-EP	Δ Sn-HL	Δ ULP	Δ UL-SL
ULT@A(mm)	-0.108	-0.261	-0.006	-0.180
ULT@VB(mm)	0.028	-0.083	-0.379*	-0.098
U1-NA°	-0.261	-0.183	-0.084	-0.258
U1-SN°	-0.277	-0.247	-0.140	-0.328
U1-BT(mm)	0.102	0.158	0.451**	0.239

Table 6: Correlation coefficients (r) for upper lip profile changes at bonding. Correlation coefficients with significance have been emboldened.

*Statistically significant, $p=0.039$, $p<\alpha$, $\alpha=0.05$

**Statistically significant, $p=0.012$, $p<\alpha$, $\alpha=0.05$

UL-EP: Upper lip to E-plane, Sn-HL: Subnasale to H-line, ULP: Upper lip protrusion, UL-SL: Upper lip to S-line, ULT@A: Upper lip thickness at A point, ULT@VB: Upper lip thickness at vermillion boarder, U1-NA: Upper incisor to nasion-A point, U1-SN: Upper incisor to sella-nasion, U1-BT: Upper incisor bracket thickness.

Chapter 4: Discussion

The purpose of this study was to use a standardized cephalometric photograph to assess changes in lip profile due to orthodontic labial brackets bonded to the anterior dentition. As opposed to other studies that have been done, this study standardized the way that the photos were taken attempting to duplicate the conditions used in the standardized cephalometric radiograph (5 feet from patient, centered and level to external auditory meatus) to allow the results to be carried over to traditional cephalometric radiograph measurements and analyses of the lip profile.

Results in bonding show significant changes in LL-EP, LL-HL, LLP, ZA, LL-SL, UL-EL, Sn-HL, ULP, and UL-SL, which indicates an increase in lip procumbency. The results support those found by Lee et al³⁹ of the effect of bonding orthodontic brackets on lip profile. In their study³⁹, three dimensional analysis was done, images pre and post bracket bonding were overlaid using the inter-canthal region, dorsum of the nose, and temporal region and changes of facial points were determined in and X (transverse), Y (vertical) and Z (anterior-posterior) coordinate system. Subnasale (Sn), labrale superius midline (LsM), stomion (Stm), labrale inferius midline (LiM), and soft tissue B point (B'), which are midline structures, were found to have significant forward changes in the Z dimension. Additionally, LsM, LiM and B' were found to have significant upward (LsM) and downward (LiM, B') change in the Y dimension. Because these midline structures can be assessed on a two dimensional lateral photograph, we can compare the changes in the previous study and our findings. In the current

study, LsM and LiM (measured with LL-EP, LL-HL, ZA, LLP, LL-SL, UL-EP, NLA, ULP, UL-SL) were found to have significant increases in lip procumbency immediately after bonding brackets (Y and Z changes were not assessed separately, only total change). The current study did not measure changes in Sn, Stm, or B' as was done by Lee et al³⁹ so these results cannot be compared.

In addition, Lee et al's³⁹ study found significant changes after bonding brackets in non-midline, bilateral structures in the peri-oral area, such as CphR and CphL (right and left crista philtri, point at crossing of the vermillion line and the elevated margin of the philtrum), LsR and LsL (labrale superius right and left, midway from Cph to chelion), ChR and ChL (right and left chelion), LiR and LiL (right and left labrale inferius, point midway from Ch to LiM). Those areas with significant change are as follows: CphR and CphL in the Y (upward) and Z (forward) dimension; LsR and LsL in the X (outward for LsR only), Y (upward) and Z (downward) dimension; ChR and ChL in the X (outward) and Z (forward) dimension; LiR and LiL in the X (outward), Y (downward for LiR only) and Z (forward) dimensions. These non-midline structures could not be assessed on our lateral cephalometric photographs.

Our results shows that there are no significant changes in lip profile measurements such as LL-EP, LL-HL, ZA, LLP, UL-EP, Sn-HL, SSD, NLA, ULP, and UL-SL, immediately after debonding orthodontic brackets. In the previous studies, some showed no significant changes of lip profile during debonding^{41,43,44} and the others showed significant changes^{40-42,44}.

The results of non-significant changes in lip profile at debonding were supported by those found by Abed et al⁴³, Eidson et al⁴⁴, and Kim et al⁴¹. In the study by Abed et al⁴³ non-standardized profile photos were taken immediately before and after debonding orthodontic brackets and a reference line from center of tragus to lateral canthus of the right eye extending to modified nasion (point where reference line intersects the soft tissue profile) was used to measure angular changes to Sn, soft tissue A point (A'), LsM, LiM, B', and soft tissue pogonion (Pog'). No significant changes were found for any of the above measurements. In the studies by both Kim et al⁴¹ and Eidson et al⁴⁴, no significant changes were found in the upper lip after debonding labial brackets.

Contrasting the results from this study, Kim et al⁴¹, and Eidson et al⁴⁴ found significant changes in the lower lip profile after debonding orthodontic brackets, while Lee et al⁴⁰, and Jeon et al⁴² found significant changes in the upper and lower lip profile after debonding orthodontic brackets. In the studies by both Kim et al⁴¹ and Eidson et al⁴⁴, three-dimensional stereophotogrammetry was used to assess changes in lip profile. Pre-debond and post-debond images were overlaid using the intercanthal region, temporal region and bridge of nose. In both studies significant X (inward), and Z (backward) changes were found for ChR and ChL (ChL only for Kim et al⁴¹); and significant Y (upward), and Z (backward) changes for LiM. Lee et al⁴⁰ took lateral cephalometric radiographs of each patient at three stages, immediately before debonding (T1), immediately after debonding (T2), and a month and a half after debonding (T3). The radiographs were examined using the perioral landmarks A', Lsv (vermilion

boarder of upper lip), LsM, Lsb (point on upper lip where line intersects profile from perpendicular line drawn from glabella perpendicular at level of upper incisor bracket slot), Stms (stomion superius), Stmi (stomion inferius), Lib (point on lower lip where line intersects profile from perpendicular line drawn from glabella perpendicular at level of lower incisor bracket slot), LiM, Liv (vermillion boarder of lower lip), and B'. These reference points were measured to S-line and G'-per line (soft tissue glabella perpendicular: perpendicular line from Sella-Nasion plus 8.5° drawn from G' or soft tissue glabella) to assess significant changes. NLA and Holdaway angle^{11,12} (angle from nasion-B point to Holdaway line) were also measured. Immediately after debonding (T1 to T2), LiM to G'-per, as well as Lib, LiM, and Liv to S-line were found to have a significant backward change. These changes indicate that a significant reduction of lip procumbency was found when assessed from the lateral profile at these measured points immediately after debonding orthodontic brackets. All other measures were found to be insignificant from T1 to T2. A month and a half after debonding (T2 to T3), a significant backward change was found for Lib to G'-per as well as Lib, LiM, and Liv to S-line, which indicates a significant further decrease in lip procumbency for the above mentioned points after brackets have been removed for a period of a month and a half. All other measures were found to be insignificant from T2 to T3. From T1 to T3, a significant backward change was found for LsM, Lib, LiM and Liv to G'-per, as well as Lib, LiM, Liv and B' to S-line, indicating that more reference points have a significant backward change from T1 to T3 (a month and a half after debonding) than they do from T1 to T2 (immediately after debonding),

showing that there is a more significant reduction of lip procumbency a month and a half after debonding than there is immediately after debonding. All other measures were found to be insignificant. Jeon et al⁴² used a three-dimensional laser scanner to analyze changes by overlaying pre (T1) and post-debond (T2) as well as 3 months post debond (T4 to indicate 3 months versus T3 above indicating a month and a half) images using right and left medial and lateral canthus, and pronasale as reference points. Total displacement was measured in this study instead of breaking down the displacement in the X, Y and Z planes. All midline structures (Sn, LsM, Sto, LiM, B' and Pog') were found to have significant inward change from T1 to T2 as well as T1 to T4, indicating that there is a significant reduction of lip procumbency immediately and 3 months after debonding orthodontic brackets. All non-midline structures (CphR, CphL, LsR, LsL, LiR, and LiL) were also found to have significant inward change from T1 to T4, indicating a reduction of lip procumbency 3 months after debonding orthodontic brackets. ChL and LiL were found to have significant inward change from T2-T4, showing that there is a significant reduction in lip procumbency at those points from immediately after debonding to 3 months after debonding. These differences in findings may be due to the differences in methodology, such as a three dimensional analysis and radiographic cephalograms, versus a photographic cephalogram of the current study. These differences may also be due to measuring to different reference planes. The only reference plane from previous studies that was also used in this study is S-line from the study by Lee et al⁴⁰.

In bonding, the only significant correlation in lower lip is the moderate positive correlation between the changes in ZA and the initial LLT@B. The ZA is measured from Frankfurt horizontal (FH) and the line connecting Pog' to LiM⁴⁸. In our results, Z angle decreased at bonding, which means either LiM moved forward or Pog' moved backward relative to FH as there is no immediate craniofacial growth to change FH. This indicates that as the thickness of the lower lip at B point increases the lower lip has a tendency to become less protruded relative to the chin after orthodontic brackets are placed.

In the upper lip when bonding, there was a moderate negative correlation between the changes in ULP and the initial ULT@VB. ULP is measured from a line connecting Pog' to Sn and measured to most protrusive point of upper lip (LsM). The negative correlation of ULP to initial ULT@VB indicates that as the thickness of the upper lip increases at B point there is a decrease in the amount of protrusion of the upper lip relative to the Sn-Pog' line. This suggests that lip thickness affects the amount of protrusion observed by the upper lip due to brackets.

A moderate positive correlation between changes in ULP and U1-BT was found in upper lip during bonding. The positive correlation of ULP and U1-BT indicates that as there is an increase in bracket thickness, there is also an increase in the amount of protrusion of the upper lip. In the study by Lee et al³⁹ they found that there was no statistical difference between lip displacement ratios that were determined based on lip displacement and bracket thickness between 4 types of brackets (Metal, Ceramic, Damon, and Speed). These results support

the findings of the current study suggesting that a thicker bracket will result in an increased procumbency of the upper lip.

Although significant correlations were found, it is important to note that these correlations are moderate ($r=0.371$, -0.379 , 0.451 respectively). The coefficients of determination (r^2) range from 0.137 to 0.203, suggesting 13-20% of the changes in those specific lip profile measurements at bonding can be predicted by the specific underlying factors.

4.1. Limitations, Implications and Future Studies

The data obtained from this study can be significant in educating orthodontic patients of what to expect when undergoing orthodontic treatment. From these results, patients could be educated to understand that when braces are bonded to the labial surfaces of the dentition, they can expect their lips to appear more procumbent (or fuller). They can also be informed that there will be no immediate changes of lip profile after debonding orthodontic brackets.

Future studies could involve following the patient over a one month period to take additional profile photos to determine if there is any change to the lip profile after one month from debonding orthodontic brackets as was done by Lee et al⁴⁰ and Jeon et al⁴².

Chapter 5: Conclusions

When a patient has labial brackets bonded to the dentition there is a significant increase in the procumbency of the upper and lower lip. In the lower lip, there is a significant moderate positive correlation noted between lip thickness at B point and the changes in Z angle during bonding. In the upper lip, there is a significant moderate negative correlation between upper lip thickness at vermilion boarder and the changes in upper lip protrusion as well as a significant moderate positive correlation between upper incisor bracket thickness and the changes in upper lip protrusion. When a patient is finished with treatment and the orthodontic brackets are removed from the labial surfaces of the dentition, there appears to be no significant change in the lip profile immediately.

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